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Greenhouse Gas Mitigation through Sustainable Intensification of Livestock Production in the Brazilian *Cerrado*

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Addressing agricultural emissions is central to Brazil's National Plan on Climate Change. At the Conference of the Parties to the United Nations Framework Convention on Climate Change in 2009 (UNFCCC COP 15), Brazil proposed Nationally Appropriate Mitigation Actions (NAMAs) as part of its commitment[1]. For the period 2010-2020, the NAMAs establish targets for the reduction of deforestation in the Amazon by 80 per cent, and by 40 per cent in the *Cerrado*.

The *Cerrado* (central Brazilian savannah) is a key livestock production area and the adoption of pasture restoration (recovery of degraded pastures by chemical and mechanical treatment), and integrated crop-livestock-forestry systems (aggregation of different production systems in the same property, such as grain, timber, meat, milk and bioenergy) are also targeted in order to reduce greenhouse gas (GHG) emissions. Because such measures increase productivity (output per hectare), they avoid the need for more land to increase production. Due to the land-saving effect of these livestock-related measures, Brazil expects to reduce net emissions by between 101 and 126 million tonnes (CO_2 equivalent) by 2020, compared to baseline projections (i.e. assuming a business as usual scenario). This would account for 61 per cent of the total reduction and 73 per cent of the agricultural contribution. The NAMA proposal is enacted as part of the ambitious ABC (*Agricultura de Baixo Carbono* - Low Carbon Agriculture) programme, which offers low interest loans to farmers adopting mitigation measures. ABC has identified specific mitigation or abatement measures (Table 1). To date there has been no analysis to assess the cost-effectiveness of these measures relative to other ways of reducing emissions.

Table 1: The ABC plan: Brazil's policy to develop a low carbon emission agriculture

Measure	Commitment (area increase/use)	Mitigation Potential (Million tonnes of CO_2 equivalent)
Pasture restoration	15 million hectares (ha)	83 to 104
Crop-Livestock-Forest Integration	4 million ha	18 to 22
No-Tillage System	8 million ha	16 to 20
Biological Nitrogen (N) Fixation	5.5 million ha	10
Reforestation	3 million ha	-
Treatment of Animal Waste	4.4 million cubic metres	6.9

Source: (Mozzer, 2011).

Brazil is the world's second largest beef producer. With an output of over 9 million tonnes per year it accounted for roughly 15 per cent of global production in 2012-13 (FAO, 2014). Brazilian production is predominantly pasture-based on a grassland area of approximately 170 million hectares (IBGE, 2014), mostly with a humid or sub-humid tropical climate. But this production can entail significant external costs i.e. costs borne by wider society such as environmental impacts. To meet increasing domestic and export demand, the government recognizes the need to foster methods for sustainable agricultural intensification (SI). This implies increasing resource productivity, while minimizing impacts related to conversion of biodiversity-rich habitats to pasture and the generation of greenhouse gas emissions.

Focusing on the *Cerrado,* we outline results of an economic analysis of the adoption of targeted GHG abatement measures to achieve a 40 per cent reduction in Brazil's GHG emissions by 2020 relative to baseline projections. Our analysis takes into account both private and social costs and benefits (e.g. the benefits of avoiding deforestation). Our analysis is essentially a model-based SI study, demonstrating the extent to which specific resource efficiency measures in agriculture can help balance production and GHG emissions, while accommodating increasing consumer demand for food.

Research to date (Gouvello *et al.*, 2011; Strassburg *et al.*, 2014), suggests that increasing livestock productivity per hectare - by improving both pasture forage productivity (PFP) and animal performance - has the highest potential to reduce external impacts. In particular, increasing PFP through restoration practices can boost soil carbon sequestration - when carried out on currently degraded grasslands. In addition, increasing animal performance through supplementary feeding may significantly reduce direct methane emissions.

The *Cerrado*

The *Cerrado* (Figure 1) is the second largest of six Brazilian ecological zones (biomes[2]). It accounts for almost 24 per cent of the area of the country and is shared between 11 states that have the highest beef cattle density. The region contains around 35 per cent of the Brazilian beef herd (ANUALPEC, 2010). With a hot sub-humid tropical climate and distinct wet and dry seasons, the area consists of tropical forests, grasslands and savannah whose acidic soils are relatively infertile. The region is second to the Amazon in its contribution to land use change and forestry emissions in Brazil (Table 2). The recent global success of Brazilian agriculture is often attributed to the expansion of production into the *Cerrado* (The Economist, 2010); sometimes considered the Brazilian agricultural frontier. The region is also seen as a potential model for improving agricultural productivity in other (e.g. African) savannahs.

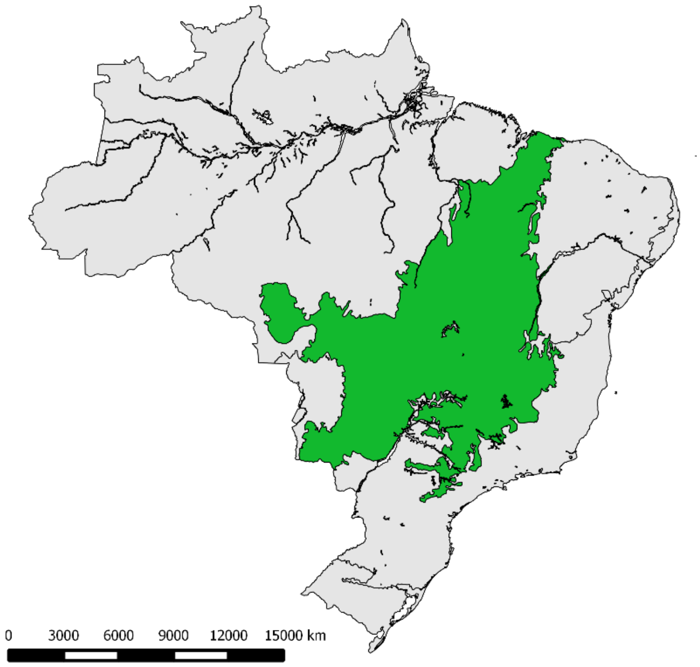


Figure 1: *Cerrado* core – the central Brazilian savannah

Planted pastures in the *Cerrado*, mainly *Brachiaria* (signalgrass) species, cover approximately 50 million hectares (Sano *et al*., 2008), and amount to approximately 34 per cent of the total pasture area in Brazil (IBGE, 2014). Roughly 50 per cent of *Cerrado* pasture is considered to be in some stage of degradation, i.e., PFP is lower than optimal levels and is unable to restore itself naturally.

Table 2: Net emissions from land use change and the forest sector in Brazil in 2010

Biome	Million tons of CO_2 equivalent	Contribution (per cent)
Amazônia	140	52
Cerrado	109	41
Pampa	16	6
Caatinga	6	2
Pantanal	2	1
Mata Atlântica	-5*	-2

Notes: * Negative emissions are due to CO_2 removal by forestry plantations.
Source: Second National Communication of Brazil to the UNFCC (http://www.mct.gov.br/index.php/content/view/326998/Full_Publication.html)

In our analysis we use a marginal abatement cost curve (MACC) approach to rank the cost-effectiveness of a range of mitigation measures. Agricultural MACCs are used to compare the relative costs of implementing these measures and the amount of mitigation they offer under average farm conditions. MACCs can be used to determine the relative cost-effectiveness of each measure in terms of cost per tonne of CO_2 mitigated. (see, for example, Moran *et al*., 2010). With this information it is possible to define the lowest cost ways to achieve a given GHG reduction target. In our case, the MACC is derived using output from a multi-period linear programming model. We represent the *Cerrado* region as a single production unit (or farm) and seek to maximize production value subject to economic and biophysical constraints (see Box 1).

Box 1: Methodology

Overview: The EAGGLE model (Oliveira Silva, 2013) is a multi-period linear programming model that represents the complete production cycle (cow-calf, stocking and finishing) on a beef farm. The model allocates farm resources optimally to meet demand projections while maximizing profit. In this analysis, the *Cerrado* beef production system is treated as a single farm.

Outputs: Profit (gross margin) and net GHG emissions are obtained by running the model for a given beef demand projection and associating the resulting animal numbers with standard emissions coefficients, land use conversion emissions (i.e. loss of biomass in terms of CO_2 equivalent) and changes in soil organic carbon stocks.

Building the MACC: By assuming the adoption of a mitigation measure '*m* scenario', the values of the outputs (profit and net emissions) are evaluated relative to a baseline without measure adoption. The abatement potential is calculated as the difference between GHG emissions under the two scenarios. Cost-effectiveness is calculated as the difference between profit, divided by the difference between emissions under the '*m* scenario' and the baseline.

The selection of GHG mitigation measures was based on a literature review and expert opinion on the relevance and applicability of specific mitigation measures to conditions in the *Cerrado*. The measures evaluated are pasture restoration, feedlot finishing, the use of feed concentrates and protein supplements, and nitrification inhibitors (see Table 3 for a description of these measures).

Table 3: Description of the mitigation measures evaluated

Mitigation Measure	Consists of:	Reduces emissions by:
Supplementation: Concentrates	Feeding cattle via grazing and a ration with a high energy content	Shorter animal life cycle by increasing weight gain
Supplementation: Protein	Feeding cattle via grazing and a ration with a high protein content	Shorter animal life cycle by increasing weight gain
Pasture Restoration	Improving pasture forage productivity by soil chemical and mechanical treatment	Avoiding the need for additional pasture land and increasing organic carbon sequestration
Feedlot Finishing	When cattle weight is around 80% of the slaughter weight it is removed from pasture and grass to feedlot on a diet with ration of balanced protein and energy content	Shorter animal life cycle by increasing weight gain
Nitrification Inhibitors	Applying nitrogen fertilizers coupled with nitrification inhibitors	Reduced conversion of nitrogen to the GHG nitrous oxide (nitrification)

Our analysis examines the direct emissions of measures applied on farms and does not account for emissions that could arise as a result of altered supply chains: so-called life-cycle impacts.

Baseline and MACC construction

Land use change scenarios, including mitigation measures, need to be evaluated with respect to a plausible baseline without mitigation activity. Our baseline scenario is based on forecasts of beef demand for Brazil - consisting of domestic consumption and exports - and projected changes in grassland area for Brazil, from 2006 to 2030, derived from Gouvello *et al.* (2011).

In the baseline scenario, beef production in the *Cerrado* accounts for an average of approximately 122 million tonnes of CO_2 equivalent per year from 2010 to 2030 (Figure 2). This figure includes enteric fermentation, animal waste (emissions from excreta), soil fertilization emissions (through nitrification), degraded pasture (hence loss in carbon stocks), and land use conversion driven by beef production. The accumulated emissions from 2010 to 2020 account for about 1,250 million tonnes (CO_2 equivalent) or 2,550 million tonnes from 2010 to 2030.

In relative terms, enteric fermentation contributes most: 66 per cent of total emissions from agriculture, followed by land use conversion, with 26 per cent. The results also show that pasture degradation and animal waste are significant sources of emissions, each accounting for 4 per cent of total agricultural emissions (Figure 3). Emissions associated with the use of nitrogen fertilizers are not significant, since only small amounts are used to fertilize *Cerrado* pasture soils.

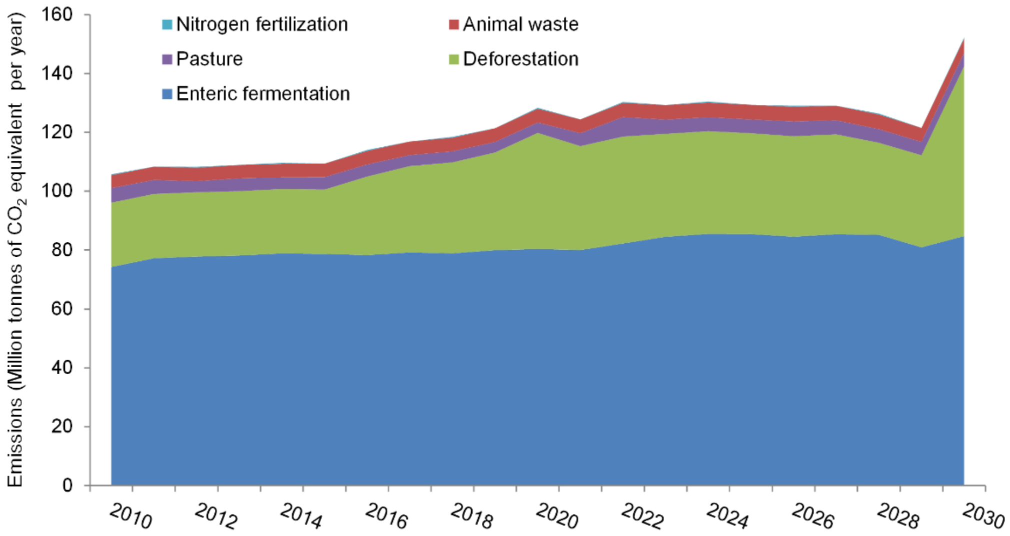


Figure 2: *Cerrado* emissions for 2010-2030 assuming that no GHG mitigation measures are adopted

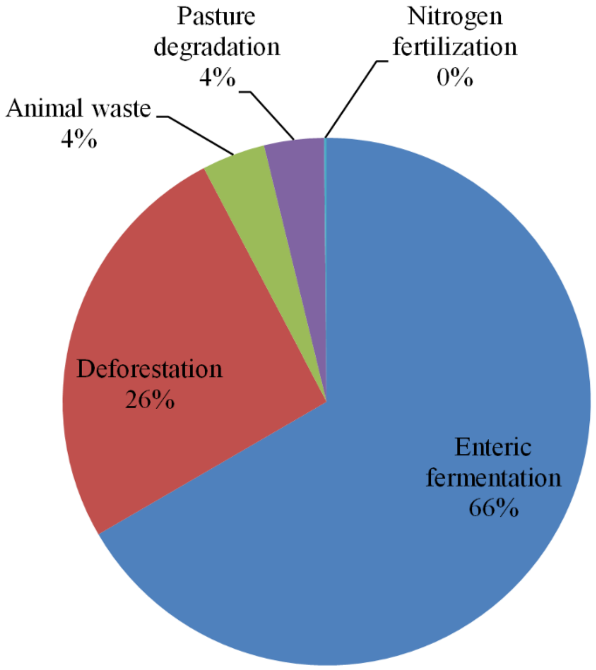


Figure 3: Estimated shares of emissions from 2010 to 2030 for the Brazilian *Cerrado*

Gouvello *et al.* (2011) suggest that Brazil's total GHG emissions from energy, transport, waste, deforestation, livestock and agriculture - will be around 1.7 billion tonnes (CO_2 equivalent) in 2030. The results presented here suggest that beef production in the *Cerrado* will be responsible for about 152 million tonnes, corresponding to 9 per cent of the national total.

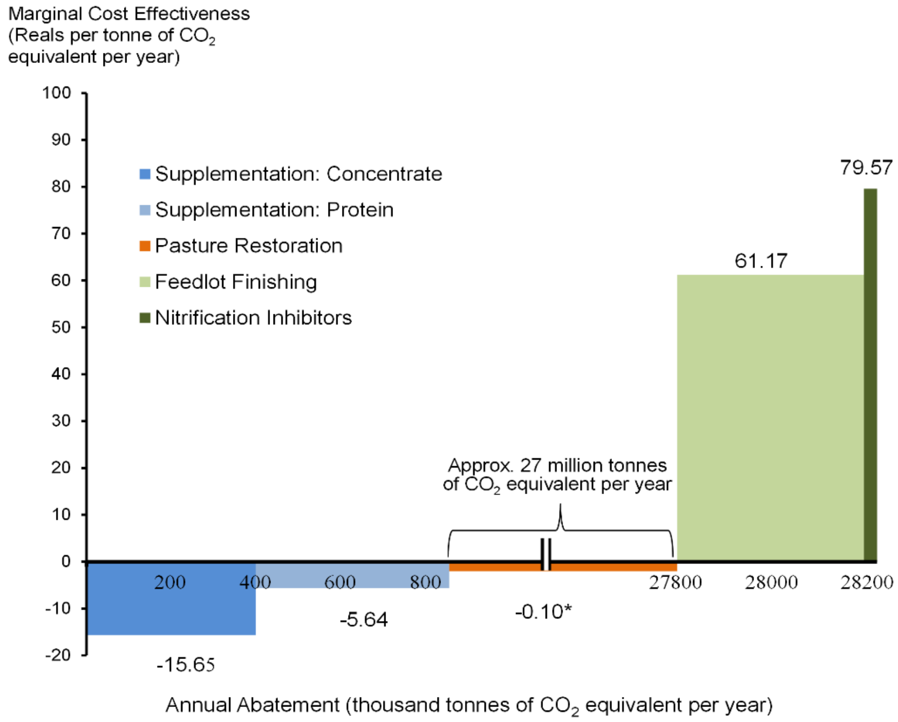
The estimated average native habitat conversion rate for the period to 2030 is approximately 246 thousand hectares per year. In the baseline scenario, it is assumed that PFP remains at 2006 levels, and so the calculated conversion rate can be interpreted as the additional area required for beef production in *Cerrado* to meet the projected demand for beef under 2006's PFP levels.

Table 4 shows the abatement potential and cost-effectiveness of the mitigation measures outlined in Table 3. Figure 4 shows the marginal cost effectiveness of the measures..

Table 4: Cost-effectiveness (CE) and abatement potential (AP) of mitigation measures

Mitigation Measure	Cost effectiveness (CE) Reals per tonne of CO_2 equivalent*	Abatement potential (AP) in thousand tonnes of CO_2 equivalent per year
Supplementation: concentrates	-15.65	399.6
Supplementation: protein	-5.64	456.1
Pasture restoration	-0.10	26,898.5
Feedlot finishing	61.17	439.6
Nitrification inhibitors	79.57	31.4

* Brazilian reals (R$) expressed in 2012 values. The Real is roughly equivalent to 0.32 Euros



* Out of scale representation

Figure 4: Estimated marginal abatement cost schedule for mitigation measures in *Cerrado* livestock production, 2006 to 2030

Three of the five mitigation measures analysed - concentrate supplementation, protein supplementation, and pasture restoration - have negative cost-effectiveness. This means that the adoption of these measures generates cost savings in beef production, while also reducing emissions.

Supplementation measures increase profit by reducing the life cycle of steers. By providing an extra source of feeding during the winter, when forage productivity is at low levels (due to low rainfall), these measures allow the system to maintain optimal stocking rates regardless of seasonal productivity variations. This contributes to higher profits.

Pasture restoration provides the greatest opportunity for reducing emissions in the *Cerrado* region. This is due to a combination of the large applicable area (approximately 60 million hectares), which is based on deep-rooted grasses (mainly varieties of signal grass) able to sequester significant amounts of carbon in the soil, and due to the fact that increased productivity in feed production reduces the need to clear additional areas for grazing.

The abatement potential (AP) for pasture restoration is roughly 27 million tonnes of CO_2 equivalent per year, made up of two components: carbon sequestration and avoided land use conversion. The latter, driven by the need to clear land for pasture, accounts for 96 per cent of this potential.

Pasture restoration would improve average forage productivity in the *Cerrado* by between 10 and 11 tonnes of dry-matter per hectare per year, an increase of 12 per cent relative to the baseline. This increase would lead to an average sequestration rate of 0.32 tonnes of CO_2 equivalent per hectare per year.

The AP of feedlot finishing is 470,000 tonnes of CO_2 equivalent per year, but the cost of the measure, at around R$ 61 per ton of CO_2, is high relative to supplementation. This is due to large investment costs for feedlot installations and the costs of specialised labour.

Nitrification inhibitors are the least cost-effective measure considered. But our analysis only considered the application of inorganic nitrogen for pasture and crop fertilization and excluded the application of animal waste. Although the use of inhibitors is not feasible for grazing animals, it could be applied to manure from feedlot animals.

In conclusion, the results indicate that restoring degraded lands offers the greatest opportunity for reducing emissions in the *Cerrado* given projected future demand for beef. The abatement potential of this measure is about 20 times greater than all the other measures combined.

Discussion

Our results suggest that a significant contribution to Brazil's sustainable intensification objective can be made by targeting measures that improve system productivity in terms of output per hectare. Specifically, pasture restoration, the use of feed supplements and feedlot finishing of animals could reduce sector emissions by 24 per cent by 2030 compared to a "business as usual" scenario. Moreover, the adoption of cost saving measures in production offers the potential to realize virtually all this reduction in emissions. Currently, it is estimated that only 10 per cent of Brazilian pastures are being managed using restoration practices. Achieving a higher rate restoration rate is likely to entail some initial investment costs to promote improved production practices and this is the purpose of the government's ABC programme.

ABC is an ambitious plan to stimulate the adoption of mitigation measures by farmers and ranchers in order to meet the GHG reduction targets presented at COP 15. ABC is the currently the largest source of subsidized credit for the agricultural sector. The plan targets the restoration of 15 million hectares of pasture land over 10 years, which will lead to reductions of up to 104 million tonnes of GHGs (CO_2 equivalent), roughly 64 per cent of the programme's total mitigation potential. The programme does not include other relevant measures such as feed supplementation, which would normally be considered to be privately profitable.

The analysis discussed in this article could be further refined by using a more detailed representation of the biophysical heterogeneity of the *Cerrado* biome and a more detailed treatment of how improving the productivity of existing land in agriculture could contribute to a reduction in deforestation. These issues are worthy of further research. Nevertheless by highlighting cost-effective policy options for GHG mitigation, our analysis contributes to understanding sustainable intensification processes that are relevant to Brazilian livestock production.

Notes

[1] NAMAs are essentially voluntary mitigation commitments from non Annex 1 developing countries that may be offered up for validation to UNFCCC and potentially for international compensation (either through multilateral or bilateral channels or the market) pending certification of their quality (*e.g.* permanence). Due to their biophysical complexity, to date, agricultural NAMAs have been slow to develop relative to those from other sectors.

[2] The others are Amazônia (Amazon), Pantanal, Caatinga, Mata Atlântica, and Pampa (IBGE, 2014). Although Amazon deforestation has slowed significantly since 2005, the region still dominates national emissions due to land use change and forestry (Table 1).

Further Reading

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Summary

Brazilian greenhouse gas emissions (GHG) are projected to reach 3.2 gigatonnes (CO_2 equivalent) by 2020. The government has made a voluntary commitment to reduce this figure by 40 per cent. A reduction in deforestation and livestock mitigation measures are key components of this commitment. Focusing on the *Cerrado* core (central Brazilian Savannah), we analyse abatement potential and cost-effectiveness of GHG mitigation measures applicable to livestock production. We focus on the role of intensification measures, particularly pasture restoration and animal performance to meet the objectives of increasing beef production to meet higher demand, while simultaneously reducing emissions. We use a linear programming model that optimizes pasture intensification levels according to biophysical and economic parameters and growth in beef demand. We estimate changes in soil carbon stocks generated by pasture management and land use change. According to a baseline projection, beef production in the *Cerrado* accounts for an average of approximately 122 million tonnes of CO_2 equivalent per year from 2010 to 2030. The results of our analysis suggest that by implementing cost-effective measures projected emissions in the region could be reduced by around 24 per cent. Pasture restoration, which will reduce deforestation, is the largest contributor to these results.

Pullquote

“Restoring degraded lands offers the greatest opportunity for reducing greenhouse gas emissions in the *Cerrado*”